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Models V35B and V35RB
Digital Voltmeter
Instruction Manual

INSTR. LAB.

Part 1

Notes:

1. The V35B Digital Voltmeter Instruction Manual is in two parts. Part 1, supplied in the front cover envelope of Part 2, contains text relating to the figures, tables, schematics and parts list data of Part 2.
2. The *Appendix* contains additional V35RB information.

Originator of the Digital Voltmeter

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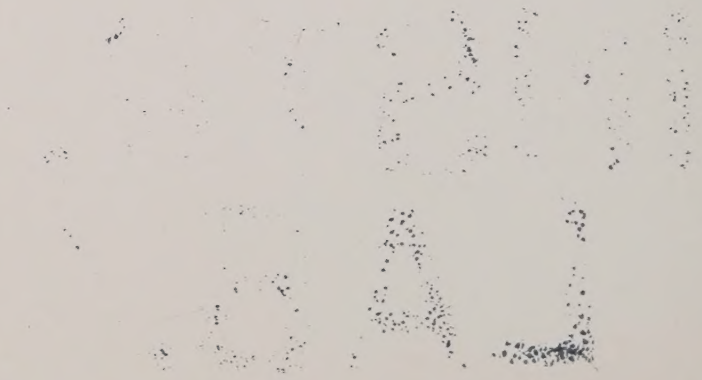

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SECTION I
INTRODUCTION

The NLS V35B Digital Voltmeter is a fully transistorized instrument designed for users who require a highly accurate, easily maintained instrument possessing a high order of reliability.

Although discussed in detail elsewhere in this manual, the leading particulars of this instrument are summarized to illustrate how NLS has met user demand and to familiarize the reader with the unit.

• RELIABLE ACCURACY

Regardless of all the features that a digital voltmeter may possess, the most important single quality needed is high reliability. The V35B has an accuracy achieved by a reliance upon a minimum of critical components rather than upon a careful balance maintained among selected parts, the failure of one of which could cause the instrument to render faulty indications. Through careful design it has been possible to control only two factors to assure high level accuracy — the zener reference supply, and the NLS manufactured decade and range resistors. As a result, other components can operate across a fairly broad band of tolerance without upsetting the accuracy of the instrument. By reducing the area of critical components to a minimum, the goal of "reliable accuracy" is approached.

• MODULAR CONSTRUCTION

Except for the power supply, all circuit components are on plug-in boards; thus it is possible to keep the V35B operative with a minimum of downtime. Hours spent in trouble shooting activities are replaced by minutes spent in module replacement. This maintenance philosophy enjoys wide acceptance among instrument users who require that both trained and untrained personnel be able to service the instrument. Digital voltmeters are sometimes integrated into large systems in which any failure can cause a whole system to shut down. To minimize downtime, the V35B has been designed around a plug-in maintenance concept.

• INDIVIDUAL PLUG-IN OIL-BATH STEPPING SWITCHES

To further simplify maintenance and repair, the stepping switches are individually enclosed and oil-bathed so that the need for periodic lubrication is eliminated. Since the decade switches are identical, a defective one can be readily located by interchanging. Their mechanical wear is held to a minimum because the logic system of the V35B eliminates considerable needless operation. Electrical wear, as well, is minimized because separate drive circuits are used, thus avoiding the necessity for passing high current through switch contacts. For these reasons the spares requirement is minimal; under typical conditions of use, only one decade switch spare need be kept per instrument.

• RAPID ACTION LOGIC

The V35B employs a rapid-action logic which produces readout indications in less time, on the average, than earlier

models of the NLS Series 30 instruments. In common with the earlier V34A and V35A Digital Voltmeters, the V35B benefits from greatly reduced balance time when compared with all other stepping-switch-type digital voltmeters. This reduction in balance time means less stepping-switch action per readout indication, thereby resulting in longer life and reduced maintenance costs.

- PROVEN DESIGN

The V35B represents a continuation of development in the 30 Series line of digital voltmeters. This instrument employs a large percentage of the same circuitry and hardware as earlier instruments within this series. Representing a continuation of development in solid state application, this new instrument has an additional element of reliability and accuracy which has been achieved by the continued use and refinement of circuits which have been time tested in the field.

- SNAP-IN READOUT ASSEMBLY

The plug-in concept applies not only to the several boards in the instrument, but to the readout assembly as well. The lamps, lucite panes, and contacts may be removed from the front of the instrument without disturbing its position in a rack. The burnt-out lamp may be replaced in a few moments without the use of any tools.

- FULL ONE-DIGIT RESOLUTION

The V35B offers full resolution of the least significant digit and, in common with earlier instruments of the 30 Series, has a factual fifth digit with full sensitivity.

- AUTOMATIC RANGE AND POLARITY SELECTION

The V35B Digital Voltmeter has automatic range and polarity selection. This feature further contributes to the simplicity of operation which characterizes earlier instruments of this series. The decimal point and polarity signs properly adjust themselves regardless of input voltage. The possibility of damage from having selected too low a range for measurement is thereby eliminated. The user can indiscriminately apply an input of a very few millivolts, obtain his reading, and then apply up to 1000 volts to obtain a reading without having to manipulate any controls on the digital voltmeter. In addition, the voltage range may be selected manually when desired, and locked into a particular range for DC measurements, or for AC measurements when used with an NLS 125 Series AC to DC Converter. When used with a 125E AC to DC Converter, the V35B provides automatic range selection of AC voltages.

- ISOLATED INPUT

The V35B input is completely isolated from the chassis. Measurements may be made with both signal "high" and signal "low," either above or below the chassis ground.

- INPUT FILTER

An input filter provides 60 db attenuation at 60 cps. The filter may be switched in or out by means of a front-panel control.

- INSTANT VOLT-TO-RATIO CHANGEOVER

The simple operation of a front-panel control permits rapid change from one mode of operation to another. No connections or disconnections need be made each time the instrument is shifted from one function to the other.

- REMOTE CONTROL

The V35B provides plug connections for remote control. Except for ratio measurements, all functions normally controlled from the front panel may also be remotely controlled.

- COMPACT, TRANSISTORIZED DESIGN

Since vacuum tubes are not used in the V35B, a remarkably compact design has been achieved. By using solid-state devices throughout, it has been possible to design and build an instrument which occupies only 5¼ inches of standard rack space.

- STANDARD INSTRUMENT FULLY EQUIPPED

The V35B is supplied complete; there is no need for accessory equipment to allow the instrument to work with printers. Self-contained contact closures are provided to actuate external indicating or printing devices.

If there are any questions about this instrument which are not covered by the manual, please contact the NLS Sales and Service Representative in your area, or contact the main plant at Del Mar, California. NLS Regional Offices are listed in the *Appendix* to this manual.

SPECIFICATIONS

ABSOLUTE DC MEASUREMENTS	
Ranges	±0.0001 to ±999.99 volts in steps of ±9.9999/99.999/ 999.99 volts.
Accuracy	±0.01% of reading or ± 1 digit
Resolution—Filter Out Filter In	±1 digit ±3 digits
Input impedance at balance	10 megohms

DC VOLTAGE RATIO MEASUREMENTS	
Range	±00.001% to ±99.999%
Over-all accuracy	±0.005% or ±1 digit
Input impedance at balance (for signal)	1000 megohms
External reference voltage	±10 to ±100 VDC
Input impedance (for reference)	50 K ohms
BALANCING TIME	2.36 seconds, maximum
RANGE CHANGING	Automatic or manual as selected.
POLARITY INDICATION	Automatic
AC MEASUREMENTS	Use accessory 125C Converter for manual or 125E for automatic range selection.
POWER REQUIREMENTS	115 volts ±10%, 60 cps, 20 watts standby, 50 watts balancing.
LOW LEVEL DC MEASUREMENTS	Use NLS 141 DC Preamplifier.
SIGNAL LOW CONNECTION	Signal low is isolated from frame of instrument, and a difference in potential of up to ±200 VDC may exist.
WEIGHT	Net 45 lbs.; shipping, 48 lbs.
PAINT, FRONT PANEL	Light gray (MIL-E-15090B, Type 3, Class 1).

Specifications are subject to change without notice.

SECTION II
INSTALLATION AND OPERATION

I. Primary Power

The V35B Digital Voltmeter operates on 105-125 volts AC, 50-60 cps. If the instrument is to be used with a 230-volt alternating current source, the primary windings of the power transformer must be wired in series. See the main schematic diagram for jumper connection coding when making this change.

NOTE

The AC power cord is polarized. Correct connection *must* be made with the power source. Despite the presence of a third grounding pin, there is no real assurance that the instrument will be correctly connected since the power outlets in many installations are erroneously wired. Be certain that the power source is in agreement with the power and grounding requirements of the instrument. Check Figure 1 against the power outlet.

Before connecting the instrument, see that it is protected by a fuse of the size shown on the main board assembly schematic. The fuse is readily accessible at the rear panel and may be extracted for inspection.

While the instrument will give readings as soon as it is turned on, a 15-minute warm-up period is required for very accurate readings. For calibration purposes, a 30-minute warm-up period is recommended. Once the instrument has been turned on, it may be left in the STANDBY position for an indefinite period. This position keeps the instrument in operational readiness without imposing wear upon relays or stepping switches.

II. Signal Input Connections

The signal input cable terminates in three banana pins; red, black, and blue. The red pin is "signal high", the black is "signal low", and the blue pin is "guard ground". See Figure 2. The red and black pins completely float and have no DC connection to other circuits. The black pin *must* always have a return path to the blue pin (provided by external connections). The blue pin should be connected to the common ground point of the circuit in which measurements are to be made. When measurements relative to the common ground are to be made, the black must also be connected to the common ground. When differential readings are to be taken, the black pin must be connected to the point with the lowest impedance to the common, and the red pin to the other point. If the impedance from the black pin to the blue pin is excessive, an error due to AC bias effects will result. This error will be minimized

or totally eliminated if a capacitor of up to one microfarad value is connected from the blue pin to the black pin — providing the circuit under measurement permits. In addition, the circuitry being measured should be enclosed in a metal shield which is connected to earth ground.

When the digital voltmeter is used with an AC converter or preamplifier, or is used to measure voltages from power supplies connected to the 115-volt AC power line, the point to which the blue pin is attached should be grounded to earth for the most accurate results (see note in preceding paragraph).

Where it is undesirable to ground this point, the impedance to earth ground (from this point) must be kept at a minimum to reduce the offset caused by AC leakage currents coming from the circuit under test or from the preamplifier's or converter's power transformer.

For stable operation, the input leads must be shielded to minimize electrical pickup. This is particularly important when the impedance of the source to be measured is high. Excessive electrical noise pickup and ground loops can cause instability or an offset effect in the readings, or both.

III. External Reference Supply

An external reference supply connector is provided on the back of the instrument for use when the instrument functions as a ratiometer.

To measure the positive and negative input voltages, the ratio-measuring circuits are connected as shown in Figures 3, 4, and 5.

When operating in the ratiometer mode, it is necessary to connect a positive voltage to the red pin (REFERENCE +) and a negative voltage to the yellow pin (REFERENCE −) — both voltages referred to the common black pin (REFERENCE COMMON). The instrument logic will lock up if the external reference voltage, corresponding to the polarity sign displayed by the readout, is missing. If it is desired to measure ratios in a single polarity, a "dummy" reference must be substituted for the deleted reference. Figure 4 shows the proper connections for positive voltage ratio measurements. The dummy reference stability and value are unimportant if only the elimination of a lock up in the wrong polarity is desired. For this reason, a single carbon-zinc or mercury cell may be used. If approximately correct readings are required of voltages whose polarities are opposite to that of the main reference supply, the dummy reference voltage should approximate the main reference voltage. The circuit shown in Figure 5 should be used when testing the linearity of the instrument in both polarities.

The V35B may use up to ± 100 volts for the external DC reference supply. When used in the AUTO mode, the AUTO TRIGGER should be set at a position appropriate to the reference voltage used. With an external reference of ± 100 volts DC, the AUTO TRIGGER is to be set with the knob pointer at approximately 12 o'clock. This setting allows approximately a ± 0.8 digit change in the signal voltage before initiating a new scan. See also the AUTO

TRIGGER discussion in Part VI of this section. Less than ± 10 volts external reference may be used with the V35B but with a resulting loss of resolution.

IV. AC-DC Converter Connections

The following three connections are to be made when a converter is used.

1. The NLS Model 125C or the 125E AC to DC Converter may be connected directly to a 34-pin plug at the rear of the instrument. This plug connection supplies the converter with AC power controlled by the digital voltmeter POWER switch and makes connection to the AC range relays in the converter.
2. Connect the signal input cable to the converter.
3. A three-wire interconnecting cable is used to tie the output of the converter to the input of the digital voltmeter.
4. Replace the 1 amp. fuse (F101) on the digital voltmeter with a 1½ amp. slo-blow type.

When the digital voltmeter is switched to VOLTS DC or to RATIO, relays in the converter pass the signal input directly through to the digital voltmeter. No special shorting plug is required if the digital voltmeter is used without a converter.

V. Printer Connection

A 75-pin plug at the rear of the instrument provides connection for use with a Clary printer, IBM typewriter, Flexowriter, and other printing devices.

All decade and symbol commons as well as all numbers and symbols are brought out to the 75-pin connector so that either serial or parallel printing may be used without modifying the digital voltmeter print harness. The print command is normally wired to provide Form C circuit closures for printers such as the IBM; however, several jumper wires must be moved to provide the correct print command for a Clary printer. Instructions for this modification are shown on Figure 27.

VI. Controls

The digital voltmeter is controlled from the front panel by the six controls shown in Figure 6. The following six subsections describe the function of each control.

1. POWER SWITCH—The POWER switch has four positions:
   - OFF—At OFF the instrument is de-energized.
   - ON—At ON the instrument operates but the print command is inhibited.
   - PRINT—In this position a print command is issued automatically at the end of each reading. This position is used when operating a Clary printer, IBM typewriter, Flexowriter, etc. When a print command is issued, the instrument locks up and cannot be made to scan until the data printer so commands or the POWER switch is returned to ON. See Part VII of this section.
   - AUTO PRINT—This position functions in the same manner

as the PRINT position except that if an error in excess of the number of digits set into the auto trigger exists at the end of scan, the print command is inhibited. In the AUTO or CONTINUOUS mode, the instrument automatically recycles until a valid reading is obtained (the single-scan mode is not used with the AUTO PRINT position).

2. FUNCTION SWITCH — This control has the following three positions:
   - RATIO—For use with an external reference supply.
   - DC—For measuring DC voltage; automatic range and polarity selections are built into the instrument.
   - AC—For measuring AC voltage; the NLS 125C or 125E AC to DC converter is used with the instrument set in this position.

3. MODE SWITCH—This control offers an unusual flexibility of action. It has the following four positions:
   - SINGLE SCAN — In this spring-loaded position, the instrument makes a single voltage measurement and locks the readout.
   - STANDBY—This position keeps the instrument warm while avoiding needless stepping switch and relay wear. It also permits the readout to be locked in order to preserve a particular reading.
   - AUTO—This is the most commonly used position. With this setting, the instrument scans whenever there is a variation in the signal input amplitude but does not scan when the input is stable. The degree of change necessary to initiate a new scan is regulated by the AUTO TRIGGER control.
   - CONTINUOUS—In this position, the instrument continually scans whether or not the signal input amplitude shows any variation. This position is normally used when the instrument is part of a printer-scanner system.

4. RANGE SWITCH—This control has four positions:
   - AUTO — Range is selected automatically for DC, and automatically for AC when used with NLS 125E AC to DC Converter.
   - 1000—000.00 to 999.99 (V35B-DC)
     0000.0 to 0999.9 (V35B-AC)
   - 100— 00.000 to 99.999 (V35B-DC)
     000.00 to 099.99 (V35B-AC)
   - 10— 0.0000 to 9.9999 (V35B-DC)
     00.000 to 09.999 (V35B-AC)

5. AUTO TRIGGER CONTROL—This control is effective only in the AUTO mode for visual readout, but is effective in all modes when used with a data recorder when

the POWER switch is in the AUTO PRINT position. The AUTO TRIGGER control sets the plus-minus limits within which the signal may vary *without* triggering another scan when using the instrument visually rather than in the PRINT or AUTO PRINT positions. For the same setting of the AUTO TRIGGER control, the same plus-minus limits apply, within which the instrument will issue a print command (when used with a data recorder and with the POWER switch set at AUTO PRINT). Note that the setting of this control has no effect upon the resolution of the instrument; the loop gain is set for a nominal 0.4 of the least significant digit, and remains at this value during every scan regardless of the front-panel control settings.

The AUTO TRIGGER control circuitry is normally set so that the control covers an approximate range of ±0.8 to ± 100 digits. The range may be extended to ± 1000 or more digits by a simple adjustment of R-616, as explained in the Maintenance Section, should individual requirements dictate a change.

When this control is set to MAX and the MODE switch to AUTO, a ± .00008 volt departure from the signal voltage producing a null with the digital potentiometer voltage will initiate a scan in the basic range. It is apparent that at signal-voltage values lying "between digits" (that is, an input of 0.83625, and a reading of 0.8362 or 0.8363), any slight disturbance of the signal will initiate a scan. The AUTO TRIGGER control may be set as requirements dictate; approximate settings as follows:

9 o'clock, 75 digits
12 o'clock, 12 digits
3 o'clock, 1-2 digits

6. INPUT FILTER—This control is a sequential push switch which illuminates the legend FILTER IN when the filter is inserted in the signal input. Successive pushes alternately remove and insert the filter. The filter is of the two-section L-C type which provides an attenuation of 60 db at 60 cycles.

VII. Operation With Data Recorders

When the POWER switch is set at PRINT or AUTO PRINT, as described in Part VI of this section, the instrument will operate as follows:

1. A "print command" pulse is issued to command data printing.
2. The instrument's reading remains locked (regardless of MODE switch position) until the data printer issues a momentary Form C contact transfer "print complete" signal to the digital voltmeter. Upon completion of the contact transfer, the instrument reads and prints again when in the CONTINUOUS mode; when in the AUTO mode, the instrument reads and prints again when the input changes from its previous value.

VIII. Remote Control

Remote control of all front-panel functions, except for RATIO, is available at J-116. Schematic Drawing No. 15094, sheet 2, shows the method of remote control. All, any one, or any combination of the functions may be remotely controlled.

If the remote control cable is longer than six feet, the wires to Pins Y, Z, AA, CC, EE, JJ, and KK should be shielded; the wires to Pins A and B should be a shielded, twisted pair.

SECTION III
CALIBRATION

The calibration procedure requires that the following items (or equivalents) be used:

1. Two voltage dividers, one with 10:1 ratio, one with 100:1 ratio; each divider calibrated for a 10 megohm load; each divider at least .005% accurate.
2. Stable but not necessarily accurate DC sources of 9 to 9.999, 90 to 99.99, 900 to 999.9 volts.
3. Stable and accurate to .005% (or better) DC source of between 9 and 9.9999 volts. Nine standard cells in series will provide 9.1656 volts.

Allow the instrument to warm up for thirty minutes; remove the top cover. Follow the steps in the sequence listed in the accompanying table. The physical location of each adjustment potentiometer is shown in Figure 7.

CALIBRATION TABLE[1]

Step[2] No.	Source[3]	Ratio[4]	Readout Display[5]	Adjustment	Purpose
1R	+90 V	10:1	9 V		
2	+90 V	1:1	90 V	R-608	
3	−90 V	10:1	9 V		
4	−90 V	1:1	90 V	R-608	
5R	+900 V	100:1	9 V		Ranging
6	+900 V	1:1	900 V	R-610	
7	−900 V	100:1	9 V		
8	−900 V	1:1	900 V	R-610	
9	+9 V STD. CELLS		9 V	R-810	Absolute Accuracy
10	−9 V STD. CELLS		9 V	R-810	

NOTES TO CALIBRATION TABLE:

1. All calibration steps must be performed with the input filter "out". After calibration is completed, correspondence of "filter in" to "filter out" readings may be made as follows: use low impedance voltage source (i.e. fresh dry cells), allow reading to stabilize with "filter in" and then switch to "filter out",—reading should remain constant ± 1 digit.
2. "R" in the Step No. column means record the reading at that point. In each case the 3 following steps must show correspondence.
3. The voltage source indicated is not exactly at the voltage listed but is within the range shown under Item 2 in the first paragraph of this section. Item 3 covers the Absolute Accuracy source requirement.
4. The 1:1 ratios indicated are to be obtained with the voltage divider connected so that the 10-megohm load is constant for all adjustments.
5. The readout in Steps 1 through 4 have digital correspondence (without regard for decimal-point position) within specifications. The same requirement also applies to Steps 5 through 8.

SECTION IV
THEORY OF OPERATION

I. Basic Theory

NLS 30 Series Digital Voltmeters are basically closed loop servos in which a feedback voltage is driven to equal an unknown input voltage. The value of this feedback voltage is then displayed on the digital readout.

Figure 8 is a block diagram of the V35B instrument. The unknown input voltage is fed through the input attenuator to one side of a non-shorting chopper; the feedback voltage is fed to the other side of the chopper. The output of the chopper is fed to the error amplifier which produces one of three outputs: U, an up pulse (signal more positive than the feedback); D, a down pulse (signal more negative than the feedback); or $\overline{U}\overline{D}$, no U or D pulse (signal equal to feedback). These three pulse lines are fed to the digital logic circuits. The timing generator drives the chopper and controls the timing of the digital logic circuits.

The programmer is at the heart of the tracking scan logic used in the instrument. It routes the output pulses from the digital logic circuits to the proper stepping switch in the Kelvin-Varley divider (or to the range attenuator relays) and selects the proper output from the Kelvin-Varley divider to be used as the feedback voltage. The novel tracking scan logic of this instrument utilizes the normal output of the Kelvin-Varley divider, as well as other outputs from various points in the divider.

The Kelvin-Varley divider is fed by a precision reference voltage supply. The output voltage of this supply is very closely controlled by a stable, low-temperature - coefficient zener diode mounted in a crystal oven.

The input attenuator divides the signal by 1:1, 10:1, and 100:1; it also controls the position of the decimal point in the digital readout.

II. The Kelvin-Varley Divider and Tracking Scan Logic

Figure 9 is a simplified schematic of the stepping-switch-controlled Kelvin-Varley divider and the programmer relays.

The Kelvin-Varley divider is a decade voltage divider in which each decade has two outputs and two inputs. Each decade is identical and is composed of one 12.5KΩ and eleven 5KΩ precision resistors and a stepping switch, all contained in a plug-in oil bath can. The switch is so wired that two adjacent 5KΩ resistors are always paralleled by 10KΩ of resistance (12.5KΩ in parallel with the 50KΩ input resistance of the following decade). Thus the resulting input resistance is 50KΩ and the output voltage across the two resistors is one-tenth of the input voltage. In addition, this voltage may be positioned at any 10% increment of the input voltage. Each decade therefore has a low and a high input and a low and a high output. Shown here in tabular form are the various output voltages for a low input of 0 volt and a high input of 10 volts.

Two additional levels on the stepping switch provide data to the readout and to the external printer connector.

Digit Displayed In Readout	Low Output Voltage	High Output Voltage
0	0	1
1	1	2
2	2	3
3	3	4
4	4	5
5	5	6
6	6	7
7	7	8
8	8	9
9	9	10

As shown in Figure 9, the decades are so connected that each decade floats on the output of the preceding decade, dividing in turn the input voltage by ten. If the signal is numerically greater than the low output, and is numerically less than the high output of any given decade, then the signal voltage lies within these limits. The logic, in conjunction with the programmer and the error amplifier, scans from right to left (from decade 1 toward decade 5) until the decade is reached whose outputs bracket the signal. When this point is reached, the scan is reversed, and the decade immediately to the right of the decade causing the reversal of scan is adjusted so that its outputs bracket the signal. The scan is continued to the right, adjusting each decade in sequence until decade 1 has been so adjusted. From the foregoing it can be seen that the instrument scans to the left *only* as far as required. That is, if only the first decade is required to move to achieve balance, the scan will go from decade 1 to decade 2 at which point reversal occurs and decade 1 is adjusted for balance. In this respect, the instrument performs in the same manner as a conventional continuous-balance-type stepping-switch digital voltmeter, the important difference being that, as with the earlier V34A and V35A, no needless steps are made; the stepping switches move *only* if so required to achieve final balance.

Figure 9 shows the zener reference supply feeding through the polarity relay and the calibrating resistor R-1 to the divider. R-1 is adjusted so that the readout agrees with a standard calibrating signal voltage. The 50KΩ resistor on the output of the divider is added to properly load decade 1. Note that only the low output of decade 1 is used since it is the final output of the divider, and bracketing is not necessary.

To determine the most significant decade requiring a change when scanning from right to left, it is not necessary to sample both high and low outputs of the decades. If, when at the end of scan just preceding the initiation of a new scan, the signal voltage is numerically greater than the feedback voltage, only the high outputs need be sampled. Conversely, if the signal voltage is numerically less than the feedback voltage, only the low outputs need be sampled. The logic symbol (+) indicates that the signal is numerically greater than the feedback and (−) indicates the reverse, without regard to polarity. When in positive polarity, an amplfiier UP is equivalent to (+), while a DOWN

is equivalent to (−). When in negative polarity, these equivalents are reversed, UP = (−), DOWN = (+), so that logically (+) and (−) are the same for both polarities.

At this point let us assume that a (+) is present just prior to the initiation of a scan. Upon scanning the high outputs of each decade from number 1 up, a (+) will be obtained until the decade is reached whose high output is numerically greater than the signal, and a (−) will occur. At this time, the scan is reversed. Conversely, if a (−) is present initially, a (−) will be obtained until the decade is reached whose low output is numerically less than the signal, and a (+) will occur, reversing the scan. *Turn-around occurs upon the first reversal of error.* If a reversal is not encountered by the time decade 5 has been sampled, the scan continues to counter position 6 — relays K-10 and K-11, Figure 9. The reference high (K-10) is sampled for an initial (+) error. If at this point a (+) still exists, an UP range signal occurs each bit until a (-) error is obtained. At this time the correct range has been reached, and the scan is reversed. If the initial error is (−), the reference low (K-11) is sampled, and if the error remains (−), a change-polarity signal occurs. When the polarity changes, the previous (−) error becomes (+) and the scan is reversed.

Down ranging is accomplished digitally without reference to error sense. If a zero is present in the fifth decade and the decimal does not indicate the basic range, a zero range (ZQ) command is issued. ZQ is always checked on the forward scan at C-2 and on the reverse scan at C-4. When changing the RANGE switch from a fixed range to AUTO range, it is quite possible that a ZQ will be required — the forward C-2 check takes care of this condition. The reverse C-4 check occurs after a normal forward scan and reversal, and after decade 5 has been correctly set (high and low outputs bracketed). If decade 5 is set to zero and the decimal does not indicate the basic range, a ZQ is issued at C-4 and at the same time M-1 causes F and LH to be zeroed. The scan is now turned around to forward and the counter proceeds to C-5 as in a normal forward scan. If required, a normal $\triangle Q$ signal can now be issued at C-6; thus the range may have started at LD_2, been zeroed (ZQ) to LD_1, and upranged ($\triangle Q$) to LD .

The timing generator controls both the chopper drive and the stepping-switch drive. Each sample of the chopper will generate a pulse out of the amplifier, U, D, or $\overline{U}\,\overline{D}$ on one of three pulse lines.

Stepping switches operate in the following manner: a pulse energizes the switch coil which, in turn, cocks a spring without moving the switch. At the end of the pulse, the spring moves the switch. Thus the switch moves only one step for each pulse. As long as a stepping switch is being pulsed, CP (compute pulse) exists, and the programmer logic is inhibited until the particular decade has been properly positioned.

In order for a particular decade to be properly positioned, two conditions must exist: the low output must be equal to or less than the signal, and the high output must be greater than

the signal. When scanning from left to right, the programmer first connects the low output of a decade to the feedback. If the low output is not equal to or less than the signal, CP's will occur and the decade switch will be driven one step at a time until the required condition is met. Since the switch mechanically moves in one direction, 0 to 9, the switch will move up to 9, and on the next step will go to 0. At this point, the feedback should be equal to or less than the signal. As a result, CP's will stop, producing $\overline{CP}$, and the programmer moves to the high-output position.

When the programmer connects the high output of a decade to the feedback, CP's are generated unless the feedback is greater than the signal. If the feedback should equal the signal at this point, a CP must be generated since an exact null cannot be reached unless the decade switch is advanced one more step. (Example: a 6.0000-volt signal cannot be nulled with decade 5 in the 5 position.) Thus the term (+)+(0) is used in place of (+) except in the first decade. ((10) meaning no error.)

Each decade stepper amplifier is driven by pulse signals derived from an individual matrix using the tabular information presented in Figure 10; also see the simplified logic schematic, Figure 23.

The following glossary of terms used will prove helpful in understanding the logic.

Symbol	English Equivalent
(+)	Signal numerically greater than feedback
( )	Signal numerically less than feedback
(+)+(0)	Signal numerically equal to or greater than feedback
△P	Change polarity signal
△Q	UP range signal
AES	Gain cutback signal to amplifier
B	Left to right scan (backwards)
C-1 thru C-6	Counter positions 1 through 6
$\overline{CD_1}$ thru $\overline{CD_5}$	Stepper coil drive, Decades 1 through 5
CP	Compute pulse, decade being driven
$\overline{CP}$	No CP, decades quiescent
D	Amplifier DOWN pulse
$\overline{D_1O}$ thru $\overline{D_5O}$	Decade at zero, Decades 1 through 5
$\overline{D_1 9}$ thru $\overline{D_5 9}$	Decade at nine, Decades 1 through 5
D_1S thru D_5S	Drive power amplifier signals, Decades 1 through 5
ES	End of scan
F	Right to left scan (forward)
LD_1	Decimal is between Decade 4 and 5
LH	LOW output of decade or reference (LOW-HIGH, FF)
$\overline{LH}$	HIGH output of decade or reference (LOW-HIGH, FF)

Symbol	English Equivalent
M-1	= Matrix feedback information to the LH & F FF's
M-2	= Matrix feedback information to the turn around FF's (F & B)
MS	= Mode signal (start scan)
P	= Positive polarity
$\overline{P}$	= Negative polarity
PC	= Polarity control to the LH FF (Do not confuse with PC on "C" board, Print Command)
PD	= Print declare
PE	= Print enable
PF	= Print feedback
REF H	= High reference
REF L	= Low reference
SH	= Scan hold
$T\cdot\overline{C}$	= Basic timing pulse
U	= Amplifier UP pulse
$\overline{U}\,\overline{D}$	= Neither UP nor DOWN
ZQ	= Zero range signal

In all 30 Series instruments, a logic term is: −12 volts (approx.) when true, and ground (zero volts) when false. The following illustrations should prove helpful.

A flip flop has two states, set and reset. Taking the ES FF as an example: when set ES = −12 (true) and $\overline{ES}$ = 0 (false), when reset ES = 0 (false) and $\overline{ES}$ = −12 (true). The statement, "$\overline{D_1 0}$ thru $\overline{D_5 0}$ = decade at zero, decades 1 through 5" is confusing when it stands alone. However, if it is understood that the zero, nine and decimal information are ground (false) when the zero, nine or relevant decimal is illuminated, and −12 when dark, then the quoted statement becomes clear. When using logic terms in logic circuitry, it is often advantageous to use the $\overline{X}$ term (not) rather than the X term. A complete discussion of types of logic circuitry used is presented later in this section.

Scan reversal, or "turn around", is accomplished in two steps. At the beginning of each scan (right to left) both the F and B FF's are in the zeroed state. Upon receipt of the *first* reversal of error signal the F FF is set. The set trigger to the B FF is derived from an AND gate composed of F, $T\cdot\overline{C}$ and $\overline{CP}$. Thus when F is set and $\overline{CP}$ is −12 (no decade switch drive), the next $T\cdot\overline{C}$ timing pulse will set B and the turn around is complete. Three lines in Figure 10 are marked with asterisks. When the logical combinations indicated by these lines occur (it will be noted that $\overline{B}$ is a common factor), the decade to the right of the indicated counter position is driven to zero. As long as any decade is being driven, $\overline{CP}$ = 0 and B cannot be set. Thus, as an example, decade 5 is driven to zero while the counter position is 6 and the feedback is Reference Low. Since decade 5 is not connected to the feedback at this time, the feedback remains constant while decade 5 is being stepped to zero. When the turn around is completed, as previously stated, B is set and $\overline{B}$ goes to zero, setting LH. Thus the feedback is connected to the low output of the first decade to be adjusted (see Figure 10). At the same time, the four-element AND gate into the commutatively coupled trigger to the LH FF (composed of $\overline{ES}$, B, $\overline{CP}$,

and $T \cdot \overline{C}$) is unlocked when B goes to -12, if CP is -12 ($\overline{ES}$ is -12 except at the end of scan). Under these conditions, the first time $T \cdot \overline{C}$ goes to zero, LH will change state. Thus, the decade will be driven (if required) until the logical conditions are satisfied for low feedback. At this time $\overline{CP} = -12$ and $T \cdot \overline{C}$ changes the state of LH. Again, the decade will be driven (if required) until the logical conditions are satisfied for high feedback. At this time the state of LH is changed again (back to set, LH $= -12$), and $\overline{LH}$ goes to zero which drives the counter backward one step. This procedure is repeated until the counter has reach standby (C-1).

Automatic polarity and ranging are accomplished by relays. Two relays are used for polarity, one to switch the zener reference supply, and one to provide the readout and print data. Four relays are used for ranging, two to switch the input attenuator, and two to provide readout and print data. All of the relays are connected as flip-flop loads. The range relays are driven by two commutatively coupled flip-flops, which can provide four ranges. When the RANGE switch is not in the AUTO position, the range flip-flops are locked in the condition commanded by the RANGE switch.

III. End-of-Scan and Print Logic

When the counter reaches C-1 (STANDBY position), LH continues to flip each time $T \cdot \overline{C}$ goes to zero. With the counter at C-1, only the low feedback is used, but the low-high logic of the more significant decades is still followed (see Figures 10 and 11). After the high logic of C-1 has been completed, LH flips once more to set. At this time, $\overline{LH}$ goes to zero, setting the SH FF. Almost simultaneously $\overline{SH}$ goes to zero, setting the ES FF, and the next time $T \cdot \overline{C}$ goes to zero, PE is set. Conditions are now set up to allow the PD FF to be set, providing the PRINT-POWER switch is set to PRINT or AUTO PRINT. If set to PRINT, a print command will be issued the next time $T \cdot \overline{C}$ goes to zero. If set to AUTO PRINT, a print command will be issued if $\overline{UD}$ remains -12 during the period from when PE is set to the next time $T \cdot \overline{C}$ goes to zero (at this time SH is reset, resetting PE). If $\overline{UD}$ goes to ground during this period, ES is immediately reset and PD cannot be set, thus inhibiting the print command. In AUTO PRINT a print command will be issued only if the readout agrees with the signal voltage within the $\pm$ limits set by the AUTO TRIGGER control. If a print command has been issued, the instrument will remain locked in the standby condition until a print feedback pulse is received from the printer, or until the POWER switch is set back to ON.

IV. Logic Circuitry

Figure 12 is an example of DC level AND-OR gates. If X_1 or X_2 (or both) are at ground potential, e_1 will be at ground. If both X_1 and X_2 go negative, e_1 will be pulled negative by R_1. Thus if both X_1 and X_2 are negative, e_1 will be negative. The same applies to e_2 with respect to X_3 and X_4. The ohmic value of R_2 is always several times that of R_1. If both e_1 and e_2 are at ground, e_3 will also be at ground, but if either e_1 or e_2 goes negative, e_3 will also go negative. The output of the circuit in

Figure 12 may be expressed: $X_1 \cdot X_2 + X_3 \cdot X_4$. This means that the output is negative if X_1 and X_2 are negative or X_3 and X_4 are negative.

Figure 14 is a sample flip-flop trigger circuit used in the V35B. X_1, X_2, and X_3 are fed into an AND gate. When they all go negative, e_1 will be pulled negative by R_1 if X_4 is -12. Since R_1 is very large compared to R_3 and R_4 in parallel, the current through C_1 will be small, and the voltage at e_2 will remain near zero. When X_1, X_2, or X_3 goes to ground, a surge of current limited by R_2 (R_2 is small compared to R_3 and R_4) will flow through C_1, causing e_2 to go positive. The PNP transistor is turned off when e_2 goes positive with respect to ground. If X_4 is ground, e_1 remains at ground and can't go positive; thus X_4 may be used as a fourth AND gate element.

Figure 13 is an example of an AC coupled AND gate. If X_1 or X_2 or X_3 (or any two or all) are at -12 volts, the following conditions will exist:

- the DC level of e_2 will be -12 volts,
- CR-1 will be reverse biased -12 volts, and
- e_3 will remain at ground (unless e_1 exceeds a 12-volt swing).

If X_1 and X_2 and X_3 are *all* at ground,

- the DC level of e_2 will be ground,
- CR-1 is now zero biased and will conduct all potentials that are positive with respect to ground. This type of AND gate is used to "turn off" a PNP transistor in an FF. Note that this gate is inverse to the DC gate shown in Figure 14. In Figure 14, X_1, X_2, X_3, X_4 initially *must all be true* (-12V). Thereafter, the first time X_1, X_2 or X_3 goes to ground, a positive pulse at e_2 will turn off the transistor. The AC coupled gate, Figure 13, requires that X_1, X_2 and X_3 must *all be false* (0 V) and the first time the trigger pulse (e) goes to ground, a positive pulse at e_3 will turn off the transistor.

Figure 15 is a schematic of a typical logic FF used in the V35B. The FF has two outputs, X and $\overline{X}$. If X is negative, $\overline{X}$ is 0, and if X is 0, $\overline{X}$ is negative. Figure 16 illustrates the flip-flop with its trigger circuits. The 27KΩ resistors connected to the collectors serve the same function as R_1 in Figure 14. The dotted circuit at the bottom of the diagram illustrates an additional set trigger. Parallel triggers such as this accomplish OR logic without the necessity for AND-OR gates.

V. A Board

Located on the A board are the timing generators, the (−) and (+) FF's and the polarity gate controlling their triggers and the (+) + (0) and CP pulse-shaping amplifiers. This board is shown in Figure 29. Figure 22 is a simplified schematic of the timing generators, and Figure 17 illustrates the timing of the pulses generated. The mono-stable FF is triggered from the 60-cycle power source and provides an 11⅔ ms delay from the trigger time. The timing binary FF divides the frequency by two, providing a 30-cycle square wave, T

and $\overline{T}$, the bit rate of the instrument. These two waves are added to drive the bi-stable chopper drive FF, producing an asymmetrical wave, CD and $\overline{CD}$, with a 5 ms duration and a 30-cycle repetition rate. The same addition triggers the mono-stable gate FF to produce C and $\overline{C}$ with approximately 1½ ms duration and a 30-cycle repetition rate. The center-tapped chopper coil (in amplifier) is driven by CD and $\overline{CD}$. At the end of the 5 ms square wave, C is set, and approximately ⅓ ms later the amplifier produces U, D, or no output.

The (−) and (+) FF's, polarity gate, and the (+)+(0) and CP amplifiers are shown in relationship to the B board circuits in Figure 24. The polarity gate routes the amplifier output as follows: If the polarity is positive, the polarity gate routes the U pulse to the (+) FF and the D pulse to the (−) FF. If the polarity is negative, the polarity gate routes the D pulse to the (+) FF and the U pulse to the (−) FF. The CP signal (CPS) is derived from an OR gate composed of five diodes located on the main board between J-105 and J-106. If any one of the decades is being driven, the corresponding diode will ground CPS. This signal contains unwanted spikes which must be removed. The CP amplifier filters CPS and provides rectangular wave outputs of CP and $\overline{CP}$. The signal fed to the (+)+(0) amplifier is derived by adding $T \cdot \overline{C}$ and $\overline{(-)}$. The (+)+(0) amplifier filters this signal and provides rectangular wave outputs of (+)+(0) and $\overline{(+)+(0)}$.

VI. B Board

This board is shown in Figure 30. Located on the B board, as shown in Figure 24, are the ES, SH, PE and PD flip-flops associated with the end-of-scan and print logic, the LH flip-flop which senses when "high" or "low" feedbacks are to be used, and the F and B flip-flops which control the direction the counter steps. The functions of these flip-flops have been previously described.

VII. C Board

The C board is shown in Figure 31. It contains the FF's which drive all of the relays in the instrument. A block diagram is shown in Figure 32. The print command (PC) FF is a 50 to 100 millisecond mono-stable flip-flop. It drives the print command relay, and is triggered by $\overline{PD}$ from the B board. $\triangle Q$, from the matrix board, drives the Q FF through an inverter. Q in turn drives the R FF. Q and R are connected to the coils of the two relays which operate the range attenuator. $\overline{Q}$ and $\overline{R}$ are connected to the coils of the two relays which provide range data to the readout and the external printer. The Q and R FF's are set to the lowest range by ZQ from the matrix board. $\triangle P$, from the matrix board, drives the P FF through an inverter. P is connected to the coil of the relay which switches the zener reference supply. $\overline{P}$ is connected to the coil of the relay which provides the polarity data.

The grounding of R_1L, R_2L, R_3L, or R_4L, provides means of locking the Q and R FF's in a selected manual range. In the V35B, R_1L is grounded for the

10-volt range, R_2L for the 100, and R_3L for the 1000. The grounding of any of these points shorts $\triangle Q$ to ground: Q and R remain in the condition commanded by the RANGE switch. ACL is grounded when the FUNCTION switch is set to AC. When ACL is grounded, the instrument is locked in positive polarity and the second range.

VIII. D Board

The instrument contains two identical D boards as shown in Figure 33. Each board has three identical stepping-switch power amplifiers, with input pins identified as D and output pins as C. See Schematic 11420-500, sheet 2. The power amplifier consists of a driver (2N1374) and power transistor (2N-1540). A diode, capacitor, and 4.7KΩ resistor enable the power transistor to absorb the energy stored in the magnetic field of the stepping-switch coil. The C's are connected to stepping-switch coils. The D's are connected to the programmer. The −15 volt supply is slightly higher than the B− voltage used throughout the instrument. The other ends of the coils are connected to this −15 volt supply.

IX. Programmer

Figure 23 is a simplified schematic of the programmer. Full views are shown in Figures 37, 38, 39, 40 and 41. The programmer is an assembly of three separate boards:

1. The COUNTER board contains a six-stage forward-backward counter, forward gate, backward gate and the LH inverter. The forward trigger is $T\cdot\overline{C}$ and the gate is open when ES and F are false. The reverse trigger is $\overline{LH}$ and the gate is open when $\overline{B}$ and CP are false. When the forward gate is open, the counter will count forward one step each time $T\cdot\overline{C}$ goes to ground. When the reverse gate is open, the counter will count backwards one step each time $\overline{LH}$ goes to ground. This board provides 8 outputs used by the matrix and relay board—C-1, C-2, C-3, C-4, C-5, C-6, $\overline{C\text{-}6}$, and $\overline{LH}$.

2. The RELAY board contains five pairs (HIGH and LOW) of reed relays with HIGH gates and LOW gates, one output reed relay, and eleven relay driver transistors. When LH is true, the LOW gates (5) are open. When $\overline{LH}$ is true, the HIGH gates (5) are open. The output relay (D_1L) has no gate and is energized (closed) when C-1 is true. When LH is true:

D_2L will close when	C-2 is true
D_3L	C-3
D_4L	C-4
D_5L	C-5
REF. L	C-6

Similarly, when $\overline{LH}$ is true:

D_2H will close when	C-2 is true
D_3H	C-3
D_4H	C-4
D_5H	C-5
REF. H	C-6

The RELAY board provides one output — the relay which is closed (one only) connects the selected

point in the divider to the feedback point in the amplifier.

3. The MATRIX board contains the AND-OR gates, inverters and FF memory circuits needed to furnish ZQ, $\triangle$Q, $\triangle$P, M-1, M-2 and D_1 thru D_n outputs when required. The functions of this board have been previously discussed; also see Figure 10 and simplified schematic Figure 23.

X. Amplifier

Figure 36 is a block diagram of the error amplifier. Full views are shown in Figures 34 and 35. The unknown signal is fed through the input attenuator to one side of the chopper. The input attenuator is controlled by the Q and R relays. The voltage across the chopper is limited to a nominal +15 volts by the zener diode, CR-601.

C-602 is shorted across the primary of isolation transformer T-601 for approximately 28 milliseconds. Approximately 5 milliseconds before the zero bit time, the chopper switches C-602 to the signal and C-602 charges toward the signal. Since the other side of C-602 is connected to the feedback, it is not required that C-602 be charged to the exact signal voltage; only direction of error is involved. It is desirable that C-602 be charged close to the signal in order to avoid excessive losses in the resultant error signal to T-601. The input attenuator has a maximum output impedence of 1 megohm; thus C-602 charges to approximately .95 of the signal. At zero bit time, the chopper is driven, and approximately 350 microseconds later transfers C-602 in shunt with the primary of T-601. Unless the feedback exactly equals the signal, energy has been stored in C-602; this energy is "dumped" into T-601, resulting in an approximate 1-microsecond pulse to Q-601. The direction of current flow depends upon the polarity of the error. The error pulse is amplified by a 3-stage transformer-coupled amplifier. The gain of the amplifier is controlled by R-618. If the signal is more positive than the feedback, the UP (U) FF will be set. If the signal is less positive than the feedback, the DOWN (D) FF will be set. The U and D FF's are cross coupled so that if either one of them is set, the other is held zeroed. If either U or D is set, $\overline{U}\,\overline{D}$ will be held at ground by Q-610. R-628 is adjusted so that the sensitivity of the U and D FF's are equal. $\overline{C}$ is at −12 VDC (true) most of the bit. At zero bit time, $\overline{C}$ goes to ground (false) and is set approximately 1½ milliseconds later. When $\overline{C}$ is true, U and D are zeroed and held in this condition until after $\overline{C}$ has been grounded approximately 250 microseconds. This delay is accomplished by the network composed of CR-615, and R-653.

When in the AUTO mode and in AUTO PRINT, Q-605 determines the error necessary to produce U or D when at the end of scan (ES). Q-605 is connected as an emitter follower series regulator; the voltage at its emitter will be approximately that of its base. This voltage is derived by the voltage divider composed of R-622, R-616, and R-103. R-103 is a 2.5K ohm log rheostat located on the front panel and labelled AUTO TRIGGER; R-616 adjusts the maximum digits error required to trigger a scan,

and is adjusted with R-103 set to MIN (full CCW), which grounds the auto lead. Nominally, R-616 is adjusted for 100 digits, but up to 1000 digits can be obtained. Q-604 serves as a gate which clamps the emitter of Q-605 to the zener regulated (nominally 4 volts) positive voltage source at all times except at the end of scan. Thus, the voltage supplied to the emitter resistors of Q-601 and Q-602 is held at 4 volts during scan by Q-604, and is held at a lesser voltage set by R-103 at the end of scan, resulting in a reduction of gain in Q-601 and Q-602.

XI. Zener Reference Supply

The zener reference supply, shown in Figure 42 and shown schematically on 11420-050, sheet 2, consists of a rectifier and a current regulator driving a zener-diode bridge circuit. The current regulator greatly reduces the effects of varying power-line voltage and the bridge circuit compensates for the dynamic impedance of the zener diodes. A full-wave rectifier and filter are incorporated to supply DC to the zener oven heater. The polarity relay, the binary coded calibrating resistors, and the calibrating potentiometer R-810 are also located on this board. R-804 controls the current to the bridge and R-810 is adjusted to compensate for the dynamic resistance of the particular zeners used. R-804 and R-810 are set at the factory and normally should not require adjustment unless the zener diodes are changed. These potentiometers are *not* calibrating adjustments.

XII. Relay Boards

Two relay boards shown in Figure 44 are titled "Range and Polarity" and "Function AC/DC". These boards provide means for supplying range, polarity, and function information to the readout and printer, as well as providing remote control of these items. A block diagram for these boards is impractical. For further information, consult the simplified schematic in Figure 27.

XIII. Trigger Control Board

The trigger control board shown in Figure 43 and shown schematically on Drawing Number 11430-860, sheet 2, supplies the trigger to start a scan. The trigger control consists of a flip-flop which is set by a signal selected by the MODE switch; there is a single positive-going pulse in SINGLE SCAN, repetitive positive-going pulses ($\overline{U}\overline{D}$) in AUTO when an error exists, or repetitive positive-going pulses in continuous ($T \cdot \overline{C}$). The reset is accomplished by $T \cdot \overline{C}$ and always occurs at the same bit timing, regardless of the timing of the mode signal.

XIV. Power Supply

The power transformer, as shown on the main board schematic, has two secondary windings. One winding supplies voltage to the zener reference supply and the other provides voltage for the four remaining supplies:

1. Zener oven
2. B negative
3. Negative 15 volts
4. B positive

CR-801, CR-802, and C-801 are on the

zener reference board and provide rectified DC for the +15-volt for the zener oven. CR-105 and CR-106 are on the main board, and provide rectified DC for the −15-volt and B− supplies. C-103 provides filtering for the −15-volt supply and L-101 along with C-106 provide isolation and additional filtering for B- (approximately −12.5 volts). The foregoing are all conventional unregulated supplies. CR-107 and CR-108 together with C-104, R-112, and C-105 provide a filtered B+ voltage which is regulated to a nominal +8 VDC by CR-109.

SECTION V
MAINTENANCE

This Section presents maintenance information from two points of view — the plug-in substitution method, Part I, and the trouble-shooting approach, as seen in other parts of this section.

I. Plug-in Substitution

Except for the power supply, all circuit components are assembled on plug-in boards. Thus maintenance problems are simplified to the point where the instrument can be kept operating without need for highly trained maintenance personnel.

Because of plug-in design, down time is held to a minimum; the digital voltmeter can be kept operating in locations from which it would be impractical or inconvenient to send the instrument to a repair facility or to the manufacturer. Also the complexity of the instrument poses no problem, either to the semiskilled worker or to the trained engineer, since a defective plug-in unit can be located without a detailed symptom study. Only a very few minutes are needed to replace all of the plug-in boards. By using trial-and-error techniques the digital voltmeter can be rapidly returned to service, and the defective plug-in board repaired at a later time.

In order to pursue the plug-in substitution philosophy to the fullest, a kit of spare parts should be stored with the instrument. Such kits are available from NLS in rack-mounted spare parts assemblies.

II. Main Power Supply

The power supply is the only main portion of the instrument not of plug-in design. The relatively large physical size of power supply components, coupled with its virtually trouble-free design, make plug-in replacement unnecessary. Figure 18 shows the position of the power supply as seen from the bottom of the instrument. In general, the power supply is of conventional design. Note that the DC output is not pure; the power supply will not provide a battery-like absence of peaks when its ouput is measured upon an oscilloscope. The V35B is designed to work without the need for pure, or even nearly pure, DC. If the power supply is checked for output, the following voltage chart serves as a guide:

NOTE

All measurements are made with the power source at 115 VAC. Any good 20,000 ohm-per-volt meter may be used. Readings should be accurate to ± 10%.

DC MEASUREMENTS

B− Supply	B+ Supply	−15V Supply	Oven Supply Oven Off	Oven Supply Oven On	Mode Switch Setting
−12.5	+8.1	−15.2	+19.3	+15.8	STANDBY
−12.5	+8.1	−15.1	+19.3	+15.8	CONTINUOUS (input leads shorted)

AC RIPPLE MEASUREMENTS: Set oscilloscope for peak-to-peak volts.

B− Supply	B+ Supply	−15V Supply	Oven Supply Oven Off	Oven Supply Oven On	Mode Switch Setting
.03	.02	1.0	.001	3.0	STANDBY
1.0	0.3	2.8	.001	3.0	CONTINUOUS (input leads shorted)

III. Logic Checkout Using Dummy Amplifier

If the instrument is serviced without plug-in substitution techniques, the Dummy Amplifier, supplied in the spares kit, or available separately from NLS, must be used. This amplifier is shown in Figure 19.

By simulating the amplifier plug-in assembly, the Dummy Amplifier, Part No. 3017-024, provides a simple means for checking all of the logic circuits in the instrument by providing proper loading resistors and output pulses. Either an UP (U), DOWN (D), or NO UP or DOWN ($\overline{U}\overline{D}$) may be selected by a switch. The test procedure given provides a method which assures that all of the logic circuits are functioning properly, and, in addition, provides a means for locating any malfunctioning assembly.

The Dummy Amplifier, along with its extension board, is substituted for the actual amplifier board when the tests described in this section are made. The Dummy Amplifier is used as shown in Figure 20, Dummy Amplifier Test Procedure. Note that the first column of this table indicates a particular test number which is similarly listed in Figure 21, Troubleshooting with Dummy Amplifier. Figure 20 indicates proper settings for the entire procedure. Be certain to read carefully the notes with each table. Figure 21 provides localizing hints and instructions for repair.

Consult also Figures 22, 23, and 24.

IV. Non-Logic Malfunctions

Non-logic malfunctions are limited to the zener reference supply, Kelvin-Varley divider circuits, the polarity relay, and the amplifier assembly. Malfunctions in these areas are most easily corrected by plug-in assembly substitution. The following list indicates in-

creasing order the probability of plug-in board failure:

Chopper
Range Relays
Amplifier Assembly
Programmer
Decade Switch
Zener Reference Supply

NOTE

+, −, or offset is usually caused by power plug reversal (see Section II, Part I), not by a faulty component. Improper connection to a remote printer also may be a cause of offset.

V. Amplifier Tests and Adjustments

The procedure for making gain and balance adjustments and signal-to-noise ratio measurements is here described. Figures 34 and 35 show the amplifier.

NOTE

No amplifier adjustment should be made unless tests show that all other portions of the instrument are functioning properly.

To test and adjust the amplifier, the following items, or their equivalents, are required:

1. Oscilloscope, Tektronix 533.
2. Dekavider, Model DV-411.
3. Voltage source, as shown in Figure 36.

Procedure:

a. Connect oscilloscope to amplifier as follows.
   1. Ground to Pin 1.
   2. Input to TP-1.
   3. Trigger to Pin 3.

b. On the amplifier board, clip TP-3 to Pin 1. Set the voltage source to +.00050 volt and flip the MODE switch to the SINGLE SCAN position one time. The readout should display +0.0005 ± 1 digit.

c. Set the oscilloscope controls as follows:
   1. DC Input.
   2. Sensitivity, 0.2 V/CM (0.02 V/CM with 10:1 probe).
   3. Sweep Rate, 100 microseconds /CM.
   4. Trigger, external +, AC slow.

d. Set voltage source at +.0015 and observe large pulse on oscilloscope face. Center the pulse upon the oscilloscope face and expand the sweep by 50. (The pulse is very narrow and difficult to see on an oscilloscope not having the bandwidth of the Type 533.)

e. Return the voltage source to +.00050 and slowly vary the Dekavider 1/10,000 dial to obtain an absolute minimum pulse. Record the reading. The difference between the new Dekavider setting and .00050 is the offset of the DVM. If the offset is greater than .00004 (the average is .000025), there is excessive leakage or AC pickup in the signal or feedback. Correct this trouble, if it occurs, before going ahead with the amplifier adjustments.

f. Recheck the null point and proceed as follows:
   1. Set the Dekavider to a reading

which is .00005 less than the null reading just checked.

Example: If null reading is .00048, the Dekavider setting will be .00043.

2. If a steady square wave (leading edge at the same point as the error pulse) now appears, rotate R-618 CCW (counterclockwise) until the square wave just starts to "blip"; if no square wave is present, rotate R-618 CW until a steady wave appears, then CCW until the square wave just starts to "blip".

3. Clip the oscilloscope input to TP-2 and set the Dekavider to a reading .00005 more than the null reading.

   Example: If null reading is .00048, the Dekavider setting will be .00053.

4. If a steady square wave appears, rotate the balance control R-628 CW until the square wave just starts to "blip"; then return R-628 CCW one half the turns to the initial setting. If the square wave is "blipping" initially, rotate R-628 CCW until the same degree of "blipping" is present as in Step 2; then return R-628 CW one half the turns to the initial setting. The balance potentiometer should now be balanced and will need only slight readjustment in the recheck to follow.

5. It is important to notice if the amplitude of the square wave is approximately (within 20%) the same for Steps 2 and 4; if the amplitude of Step 2 is less, Q-606 is probably weak; if the amplitude of Step 4 is less, Q-608 is probably weak. Recheck Steps 1 through 4.

6. When recheck is complete, and with the settings as called out at the completion of Step 4, rotate R-618 slightly CW until the "blipping" just stops. Reduce the error of Step 3 to +.000035 (Dekavider setting of .000515 if null has remained constant). The square wave should be completely gone (no blips). If the preceding steps have been followed correctly and the square wave appears, it can be assumed that the amplifier is excessively noisy and requires repair.

7. With the setting maintained as in Step 6, but with the oscilloscope input connected to TP-1, observe the signal - to - noise ratio. The observed ratio should never be less than 3:1; a typical amplifier is 4:1. See Figure 25 for typical output wave form.

VI. Zener Reference Voltage Supply

The zener reference supply, shown in Figure 42, is a plug-in unit containing all the elements required to furnish a calibrated ± 9.9601 VDC to the feedback voltage divider. As indicated in

the Calibration Section, the only calibration adjustment is R-810 which is set after the correct jumper connections are made. All other adjustments have been made at the factory and should *not be touched* unless it is necessary to replace components. This unit should be returned to the factory for repair and readjustment.

When calibrating R-810, it is possible (due to different standards to which the DVM may be calibrated) that the limit of travel will be reached before calibration is achieved. If R-810 has been rotated fully clockwise, change the jumpers to those called out on the line above the initial jumper connection as shown in Figure 26. If R-810 is fully counterclockwise, change the jumpers to those called out on the line below the initial jumper connections.

When it is necessary to service this unit in the field, an extension board from the service and spares kit should be used to make the test points accessible. Schematic 11420-050, Sheet 2, should be consulted as a guide when making tests. Do not replace any parts or make any adjustments until the following tests have been made:

a. The voltage as measured from TP− to TP+ should be 7.7 VDC with the line voltage at 115 VAC. When the line voltage is varied from 105 VAC to 125 VAC, the regulated DC voltage measured should not vary more than ±0.2%. This measurement must be made with a device having a minimum of 500 K ohms input impedance. If the regulation is within limits and the voltage measured is not 7.7 VDC, adjust R-804 and recheck regulation. If it is impossible to achieve regulation and the correct voltage, measure the voltage across C-802. This voltage should be 36 VDC ± 1 volt at 115 VAC line voltage; if not, check CR-803, CR-804, R-802, and C-802; also check AC supply to Pins 16, 17, and 18. If the voltage is correct (across C-802), the fault is likely to be Q-801; also check CR-805 (6-volt zener), CR-806, and resistors R-803 through R-809. If the voltage from TP+ to TP− is very low or zero, CR-821 is defective or there is an "open" in the associated circuitry.

b. Connect a DC voltmeter across C-801. With the line at 115 VAC, the voltage across C-801 will be 19 VDC ± 1 volt with the oven heater HR-821 off (S-821 open). With the heater on, the voltage will be 16 VDC, ± 1 volt. Observe this voltage to determine correct operation of HR-821 and S-821.

c. Make up a test network consisting of a 30 K ohm resistor in series with a 1 mfd capacitor. Connect one end of this network to TP+ and the other to Pin 17 of the zener board. Connect the oscilloscope ground (Tektronix 502 or equivalent) to Pin 6 and the input to Pin 5 (the oscilloscope must be isolated from ground). With the digital voltmeter in positive polarity and at balance with a very low reading (e.g., 0.0005), adjust R-806 for minimum AC ripple as seen on the scope. Typically, this

ripple will be less than 1 millivolt when R-806 is properly adjusted. With the test network removed, the ripple should be less than 200 microvolts with the digital voltmeter at balance (low reading) in either polarity.

VII. Range and Polarity — Function AC/DC

These boards are shown in Figure 44 and are schematically shown on Sheet 2 of Drawings 11420-800 and 11420-830, respectively. For an overall understanding of the functions handled by these boards see Figure 27. In addition to the function indicated in the title, the 11420-830 board has components and circuitry associated with data printing functions; these components, together with the Print Relay K-101 (located on the main board), are shown in a group in Figure 27.

If trouble is encountered in any of the functions associated with the Range and Polarity boards, a study of Figure 27 should indicate the probable area of failure. Point-to-point checks for continuity, with the relays in both the energized and de-energized conditions, along with simple ohmmeter tests of diodes, should quickly locate the trouble.

To test the functions of Q-801, K-801 and K-802 (11420-800), ground Pin 4, apply + 8 VDC to Pin 5 and −12 VDC to Pin 15; Q-801 should be conducting and K-801 and K-802 should be energized. The grounding of Pin 6 should cut off Q-801, and K-801 and K-802 should be de-energized.

VIII. Digital Readout Maintenance

The digital readout ordinarily does not require maintenance other than lamp replacement or an occasional cleaning. The V35B is equipped with a readout on which removal instructions may be printed. If the readout visor carries no instructions, proceed as follows:

1. Gently lift the black readout visor and then pull outward. The readout assembly is now exposed and the retaining side brackets may be observed.
2. Spread the two retaining side brackets and gently tilt the readout forward from the top, allowing the bottom to pivot.
3. The readout is now free to continue its travel outward. Be certain to avoid exerting a direct pull; instead, allow the readout to come forward while the pivot points are seated in the pivot slots. At the end of travel, the readout can be readily removed without danger of bending the lamp contact springs.
4. To replace the readout, first engage it at the pivot points. Failure to do so may cause the lamp springs to become bent. It will be necessary to spread aside the retaining end brackets to allow the body of the readout to return to its correct position. When the readout is in place, the retaining end brackets will normally fall into position, locking the readout.

Once the readout has been removed, the lamps may be extracted. Prior to re-

placing any lamps, the contact springs for the bulbs (in the readout receptacle) should be examined. If any are bent down, they should be gently lifted to the level of the others. To locate the proper bulb position, see Figure 28 as well as a drawing provided on the main schematic at the end of the manual. Note that this is a diagram of the readout contact board, *not* the readout.

Under extremely adverse dust or humidity conditions, the individual readout plates may require cleaning. If accumulated dust particles are likely to be unusually abrasive, a camel-hair brush or artist's brush should be first used to remove loose dust particles. The plates may be cleaned with commercial isopropyl alcohol and lint-free paper such as Kimwipes 900-L, manufactured by Kimberly-Clark, Neenah, Wisconsin. The individual plates are readily slid out of their grooves by removing either structural end plate from the readout. It is well to be systematic about this operation so as to avoid replacing the plates in improper order. Care should be taken to avoid replacing the plates backwards; this sort of error is most likely to occur with plates marked 1, 0, 6, 8, or 9. Note that the engraved side always faces to the rear of the readout.

The Polaroid filter at the front of the display may be removed and cleaned in the same manner as the readout plates. Care should be taken to reinstall the filter so that the polarizing action is correct. Look through the filter at a piece of shiny metal, such as the chrome rim of a wristwatch. If the metal shows a markedly violet cast, then the filter front is the surface closest to the eye.

IX. Plug-in Component Identification and Circuits

By consulting Figures 29 through 46, all circuit references for plug-in assemblies of the V35B may be established. Accompanying each plug-in board photograph is a parts list for that board; on the opposite page is a schematic drawing of the board. Bold face type is used to aid in locating adjustments discussed in the Calibration and Maintenance Sections.

APPENDIX

WARRANTY

Non-Linear Systems, Inc., warrants each instrument of its manufacture to be free from defects in material and workmanship. Our obligation under this Warranty is limited to servicing any instrument returned prepaid to our factory for that purpose within one year of delivery to the original purchaser. Serviced instruments are returned F.O.B. Del Mar, Calif. Tubes, semiconductors, choppers, and lamp bulbs are exempted from this Warranty. Non-oil-bath stepping switches are warranted for ninety days.

Instruments returned to the factory are accepted only when prior authorization has been given by an authorized representative of Non-Linear Systems, Inc.

Non-Linear Systems, Inc., reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

No warranty issuing from any source other than Non-Linear Systems, Inc., is valid.

SHIPPING INSTRUCTIONS

Depending upon location, the choice of carrier will vary. Never ship an instrument to us without having received shipping instructions. If requested, an estimate of charges can be made before work begins.

Be certain to pack the instrument carefully; while an outer and inner box, separated by two or three inches of excelsior is desirable, the instrument can be placed into a single container provided it is so packed that it will not shift about. As with the double box method, use two or three inches of shock-absorbent packing materials. The instrument itself should be first wrapped in heavy paper so as to keep excelsior or other particles from entering the instrument's louvres. If the original shipping container is in good condition it may be used.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it does not operate or is damaged, a claim should be made with the carrier. The claim agent should receive a full report of damage, and this report sent to Non-Linear Systems, Inc. After receiving such a report, we will advise you of the disposition of the instrument and arrange for its repair or replacement. Be certain to include model and serial number when corresponding.

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NOTES

ADDITIONAL V35RB DATA

The NLS Reed Relay Digital Voltmeter, Model V35RB, is very similar to its oil-bath stepping-switch counterpart, Model V35B.

The essential differences between the two are as follows:

1. The V35RB instrument uses reed relays instead of conventional oil-bath stepping switches to perform computing, readout and printout functions.

   NOTE

   For operating external equipment such as data printers, readout information is applied in the "voltage level" form to the printout connector. This connector has the same pin designations as the V35B instrument, except that all decade commons are at ground potential. In the V35RB Model, zero volts represents "ON" and −12 volts represents "OFF." Up to 100 ma. may be switched to zero volts and up to 5 ma. may be switched to −12 volts. When switching this 5 ma. to the −12 volts, keep in mind that the return is through the readout lamps.

2. Disregard references in the manual to the two "D" boards which are used to drive the stepping switches. Instead, "E" and "F" boards are provided. These "E" and "F" boards supply signals to the appropriate reed-relay decade, where a counter matrix and buffer convert the signals into pulses which drive the reed relays.

   Drawings 11440-500 and 11440-550 show the circuitry of the "E" and "F" boards.

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